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Citation for published version:
Bobrownicki, R, MacPherson, AC, Collins, D & Sproule, J 2019, 'The acute effects of analogy and explicit instruction on movement and performance', *Psychology of Sport and Exercise*, vol. 44, pp. 17-25. https://doi.org/10.1016/j.psychsport.2019.04.016

Digital Object Identifier (DOI):
10.1016/j.psychsport.2019.04.016

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Peer reviewed version

Published In:
Psychology of Sport and Exercise

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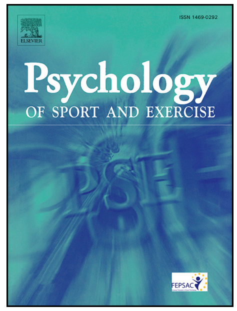

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PII: S1469-0292(18)30507-7

DOI: https://doi.org/10.1016/j.psychsport.2019.04.016

Reference: PSYSPO 1526

To appear in: *Psychology of Sport & Exercise*

Received Date: 4 September 2018

Revised Date: 10 April 2019

Accepted Date: 24 April 2019

Please cite this article as: Bobrownicki, R., MacPherson, A.C., Collins, D., Sproule, J., The acute effects of analogy and explicit instruction on movement and performance, *Psychology of Sport & Exercise* (2019), doi: https://doi.org/10.1016/j.psychsport.2019.04.016.

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Running head: ACUTE EFFECTS OF ANALOGY AND EXPLICIT INSTRUCTION

The acute effects of analogy and explicit instruction on movement and performance

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Declarations of interest: none

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Abstract

Objectives: To date, research concerning analogy and explicit instruction has focused on motor learning (i.e., change or development over many learning trials) with limited attention directed toward acute performance considerations. Accordingly, the present study examined the short-term, differential effects of analogy and explicit instructions on motor control.

Methods and design: Employing a within-subjects semi-counterbalanced design, 20 novice adult participants performed a dart-throwing task under baseline, analogy, and explicit instruction conditions. Across all throwing trials, movement and performance were evaluated using the dependent variables of throwing accuracy, elbow joint variability, angular velocity, and throw duration.

Results: Analyses did not reveal any statistically significant differences between analogy and explicit instructions for any of the study's dependent measures. Compared to baseline performances, participants in both verbal instruction conditions demonstrated significantly less accuracy, significantly greater elbow joint variability, significantly slower angular velocity, and significantly longer throwing times.

Conclusions: Findings suggest that verbal instruction may differentially affect performance in motor control situations, compared to motor learning contexts, leading to reduced accuracy; slower, more deliberate control; and increased levels of movement variability. Going forward, practitioners may need to more carefully consider not only how motor skills are instructed, but also the purpose and timing of any instructions.

Keywords: motor control, instruction, coaching, explicit instruction, analogy

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1. Introduction

To reconcile theoretical and practical issues limiting the application of implicit and explicit learning methods at the time, Masters (2000) proposed the concept of analogy instruction. These "biomechanical metaphors" (Masters, 2000, p. 538) were introduced to succinctly convey complex motor rules in an attempt to restrict the accumulation and manipulation of verbal, rule-based knowledge during performance. In the nearly two decades since then, analogy learning has been presented in the research as a popular instructional alternative to the traditional, explicit instruction typically associated with the conscious reinvestment of verbal knowledge and choking (Masters, 1992). Despite its popularity, however, in a systematic review of choking interventions, Gröpel and Mesagno (2017) lamented the "somewhat inconsistent" (p. 15) findings for analogy instruction across the literature with some studies reporting significantly better performance under pressure conditions compared to explicit instructions (e.g., Lam, Maxwell, & Masters, 2009b; Liao & Masters, 2001), but others not finding such effects (e.g., Bobrownicki, MacPherson, Coleman, Collins, & Sproule, 2015; Schücker, Ebbing, & Hagemann, 2010). According to Bobrownicki, Collins, Sproule, and MacPherson (2018), these inconsistencies do not suggest that analogies are ineffective instructional tools, but rather that researchers must more carefully consider how such instructional tools are investigated in order to advance theory, better represent real-world behaviour and, consequently, inform applied practice.

1.1. Representative and meaningful reference groups

With this in mind, one such critical consideration relates to the explicit-instruction sets against which analogy learners are commonly compared. Although instruction in real-world settings is typically provided in small chunks in a step-by-step fashion (Tse, Fong, Wong, & Masters, 2017), explicit conditions in many studies have included large instructional sets that contain not only more rules, but often additional movement information with limited

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correspondence to the analogy instructions (see Bobrownicki et al., 2018). For instance, despite the *single*-instruction analogy condition of Lam et al. (2009b) strictly describing movement during the basketball-shooting process, the *eight*-rule explicit condition not only comprised four rules describing the actual shooting movement, but also four additional instructions that detailed what to do before *and* after the shooting motion. These four added instructions, even if informative and relevant to the task, will have, at best, added artefact to the intended comparisons. Indeed, given the well documented limits regarding working memory capacity (cf., Cowan, 2001), it is certainly conceivable that these additional instructions for the explicit conditions may account for both the impaired performances and the increased number of reported verbal rules compared to analogy learning conditions. In fact, research suggests that adapting and minimising the verbose traditional explicit instruction sets to match the word volume and content of the analogy instructions reduces the size of the measured effects (Bobrownicki et al., 2015). Therefore, to better inform, develop, and drive both theory and practice, as well as address issues concerning consistency, instructional quantity and content of the experimental and reference groups should correspond and better represent real-world conditions.

1.2. Motor learning versus motor control

Another critical consideration, which is only enabled by controlling the quantity and content of the verbal instructions, concerns the systematic investigation of both effective *and* ineffective analogy and explicit instruction sets (Bobrownicki et al., 2018). In this regard, it is prudent that researchers examine not only when analogies and explicit instructions may be effective, but also aim to identify any variables that may enhance or minimise that effectiveness to enable practitioners to plan appropriately and pre-empt anticipated issues (Bobrownicki et al., 2018). In essence, with the dynamic nature of delivery in sport and

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physical education, it is critical that practitioners understand how, when, and why to deliver the myriad tools available (cf. Abraham & Collins, 2011b).

One such necessary line of enquiry identified by Bobrownicki et al. (2018) involves the short-term effects of analogy and explicit instructions. To date, interest in analogy and explicit instruction has concentrated solely on motor *learning* with limited attention paid to any potential impact of these instructional types on motor *control*—acute, short-term adjustments to, or refinement of, movement (Schorer, Jaitner, Wollny, Fath, & Baker, 2012). As Baker, Schorer, and Wattie (2018) acknowledged, there are instances in applied settings where immediate performance priorities are distinct from, and can overtake, longer-term skill or talent development processes. For instance, Gabbett and Masters (2011) noted that the constraints of time, expense, and injury can often compel coaches in rugby league to rely on verbal instruction to quickly improve player performance. In track and field athletics, it is also a common sight for coaches to verbally instruct young, inexperienced athletes between trials using new or unfamiliar instructions, unquestioningly expecting those instructions to then be implemented in the attempts that follow.

According to Schorer et al. (2012), such real-world scenarios where athletes are expected to immediately implement novel instructions often occur in the absence of the learning phases or retention tests that typically characterise the current literature. Moreover, while prior investigations in this area have typically employed the temporary factor of pressure (e.g., dual-task conditions) to evaluate learning as a function of instruction method (e.g., Liao & Masters, 2001; Poolton et al., 2007), in real world contexts verbal instruction itself often constitutes one of the temporary pressures to which learners must instantly respond. Examining the acute effects of analogy and explicit instruction would help to continue to build the knowledge base in this area and potentially assist applied practitioners

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in providing a more comprehensive instruction package that accounts for—and balances—both short-term performance considerations and longer-term skill development.

1.3. The current study

With the issues presented in the preceding sections, the current study sought to investigate the differential effects of analogies and explicit instructions—matched for quantity and content—on motor control in a dart-throwing task. The primary aim was to determine the immediate, short-term effects of matched (i.e., in terms of number of rules and content) analogy and explicit instructions and their implications for both performance outcomes (i.e., accuracy scores) and movement (i.e., elbow joint variability, angular velocity, and throwing time). To do this, a within-subjects design featuring analogy, explicit, and baseline conditions was employed. The choices of the within-subjects design and the dart-throwing task were intended to facilitate comparison to Schorer et al.'s (2012) similar investigation involving the short-term effects of internally and externally oriented instructions, while also providing some correspondence to the basic ballistic task of seated basketball shooting, which has been utilised in analogy learning studies in several instances (e.g., Lam, Maxwell, & Masters, 2009a; Lam et al., 2009b). In order to reflect the staged nature of real-world coaching delivery (Bobrownicki et al., 2018), one new instruction was provided every three throws, rather than all at once, during the verbal instruction conditions following the precedent of Wulf, Gaertner, McConnel, and Schwarz (2002).

Based on previous research (e.g., Lam et al., 2009b), explicit instructions would ordinarily be expected to promote comparable performance during learning, compared to analogies, but ultimately lead to less accurate throwing when tested under pressure because of the active control of movement engendered by accumulated verbal knowledge. Forming a priori hypotheses from this previous research, however, to predict any acute differences between analogy and explicit instructions in the current study was difficult for three reasons.

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First, the data analysis methods often employed in the preceding motor learning studies (e.g., comparisons of blocks of learning) typically involved the averaging of results over 20 (e.g., Lam, Maxwell, & Masters, 2009a; Lam et al., 2009b) to 30 individual trials (e.g., Tse, Wong, & Masters, 2017), which would serve to obscure any possible acute effects of these instruction types. Second, the disparities in the quantity and quality of the analogy and explicit instructions, as highlighted in section 1.1, mean that many previous comparisons between analogy and explicit participants (e.g., Lam et al., 2009a) must be interpreted cautiously, indeed. Third, the baseline or control groups to which analogy and explicit condition participants are often compared in earlier studies will have had significant opportunities for hypothesis testing, limiting correspondence to the baseline condition of this study and to any real-world motor control and instruction scenarios.

These issues notwithstanding, the study of Schorer et al. (2012) may provide some possible and interesting insights on possible findings for the present study. For instance, Schorer et al. found that novice participants threw more accurately in the baseline condition than in the external or internal focus conditions. Interestingly, over the course of their study, there was also no evidence of any learning or order effects, as the verbal instructions appeared to disrupt throwing performance compared to baseline conditions. For the present study, it was of interest to see whether there were, in fact, any acute performance or kinematic differences between the analogy and explicit instructions and how performance and kinematics when using these instructions compared to the baseline conditions.

Even if it is difficult to predict the precise nature or direction of any differences between the analogy and explicit instructions, it was thought that reduced accuracy, greater joint angle variability, slower angular velocity, and longer throw times would suggest more active manipulation of the instructions in working memory in line with Fitts and Posner’s three-stage cognitive framework for motor learning (1967) and associated models of choking,

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such as Masters' (1992) conscious processing hypothesis. Our hypotheses also offer correspondence with kinematic indicators of throwing performance, as research shows that changes in velocity (e.g., Smeets, Frens, & Brenner, 2002) and timing (e.g., Nasu, Matsuo, & Kadota, 2014), for instance, are associated with inaccurate throwing for darts specifically. In throwing tasks more generally, kinematic evidence also suggests that higher levels of joint variability characterise poorer or less accurate throwing performance (e.g., Fleisig, Chu, Weber, & Andrews, 2009; Yang & Scholz, 2005). If analogy instruction does offer any short-term performance advantages relative to explicit instruction, in line with its argued benefits in motor learning contexts (e.g., limited conscious manipulation), it would be expected that these advantages would be evidenced by corresponding changes in accuracy and kinematic variables, such as improved accuracy, decreased variability, and faster angular velocity, as per the aforementioned cognitive-based models (i.e., Fitts & Posner, 1967; Masters, 1992) and kinematic evidence (i.e., Fleisig et al., 2009; Smeets et al., 2002; Yang & Scholz, 2005).

Although the presented hypotheses have a basis in empirical evidence and established theoretical models, it is important to acknowledge that some characteristics of these models (e.g., conscious control and joint variability) are not necessarily undesirable and may have alternative interpretations. For instance, some evidence suggests that the same conscious monitoring or control that Masters' (1992) argues is connected to skill breakdown under pressure may also be linked with better performance in novices (e.g., Beilock, Carr, MacMahon, & Starkes, 2002; Beilock, Wierenga, & Carr, 2002) and may represent an integral consideration for skill refinement processes throughout the performance lifecycle (e.g., Carson & Collins, 2016). Correspondingly, the decreasing variability that is predicted by Fitts and Posner's (1967) model of skill acquisition and is also associated with skilled throwing (e.g., Yang & Scholz, 2005) is inconsistent with some evidence that shows variability increasing with learning (e.g., Vereijken, van Emmerik, Whiting, & Newell, 1992)

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in line with the predictions of Bernstein (1967) and the principles of dynamical systems theory. Although the premise and hypotheses of the current study are rooted in the cognitive-based models that have inspired research in analogy and explicit instruction, it was hoped that this investigation into the acute effects of these instructions, and the choice of dependent variables, would enable coaches and practitioners to plan appropriately, whatever their theoretical orientations or positions.

2. Method

2.1. Participants

Twenty novice adult participants (mean age = 23.2 years, SD = 7.35, 14 males and 6 females) volunteered for this study. Participants were considered novices if they did not play more than three times per year (Sherwood, Lohse, & Healy, 2014) and had never received any formal instruction in darts (Poolton et al., 2007). Due to previously cited issues with participants disregarding experimental instructions in favour of previously learned instructions or strategies from similar tasks (see Bobrownicki et al., 2015), potential participants who self-reported formal experience in a pre-experiment questionnaire of other throwing (e.g., javelin, cricket bowling, American football throwing) or accuracy-based (e.g., archery, shooting) tasks were not included the sample. The requisite sample size of 20 participants was determined using the G*Power programme (version 3.1) for a repeated-measures test (within factors) based on $\alpha = 0.05$, power $(1 - \beta) = 0.95$, and effect size of $f = 0.35$, corresponding with precedents in other sport-related research (e.g., Oppici, Panchuk, Serpiello, & Farrow, 2018; Van Dyck et al., 2015). The study, which was conducted in accordance with the research guidelines of the British Psychological Society (2014), received ethical approval according to the University of Edinburgh School of Education ethics subcommittee. Prior to participation, all participants provided informed consent and were advised that they could withdraw from the study at any time.

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2.2. Apparatus and task

Participants performed the task in a purpose-built sport science laboratory, using standard 24 g darts and a 1.5 m × 1.5 m dartboard placed at regulation height (1.73 m) in accordance with World Darts Federation (2014) rules. All trials were completed from a distance of 2.37 m from the dartboard, which was clearly marked on the laboratory floor. Colour-coded concentric circles, modelled after McKay and Wulf (2012), were painted directly onto the board to indicate the 11 scoring zones, which were each of equal radial width, ranging from 1 at the outermost area of the board to 11 for the bull's eye itself. Any throws that completely missed or failed to stay on the board were not awarded any score.

To facilitate automated tracking and analysis with the APAS motion analysis system (Ariel Performance Analysis System; Ariel Dynamics, Inc.; San Diego, CA, USA) , contrasting anatomical markers (see Figure 1) were placed on the acromion process, the lateral epicondyle, and the styloid process of the throwing arm (Lohse et al., 2010). A video camera (Canon MD101), positioned at an angle of 90º to the plane of the dart throw, recorded digital footage of each trial in the sagittal plane (Lohse et al., 2010) at a sampling frequency of 50 Hz in line with previous investigations involving throwing kinematics (e.g., Lohse et al., 2010; Schorer et al., 2012; Wormgoor, Harden, & McKinon, 2010). The methods of Bobrownicki et al. (2015) were used to evaluate both precision and accuracy for the digitisation. For precision, six separate digitisations of a single throwing trial returned a typical error (Hopkins, 2000) of ± 0.09º for the angle of the elbow joint. For digitising accuracy, a moving 175mm rigid segment was digitised in the same manner as the participant analyses, yielding a mean reconstructed segment length of 176 mm ± 0.75 with a mean error of 1 mm (0.6%), corresponding with results from Bobrownicki et al. (2015), Salter et al. (2007), and Wormgoor et al. (2010).

2.3. Procedure

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Participants individually performed the dart-throwing task under three different experimental conditions: baseline, analogy, and explicit. Instructions for the explicit and analogy conditions (see Table 1) were collated from a selection of sources (Kitsantas & Zimmerman, 2007; Maus, 2000), adjusted to suit the required characteristics for each verbal instructional type, and piloted with two novice participants that were not included in the final data collection. For each of the conditions, data were collected in single sets comprising 12 trials. Based on the protocols of Marchant et al. (2007), participants were informed that they would receive periodic instruction throughout the study and that their aim was to use *only* this provided information to “throw the darts as accurately as possible at the bull’s eye”. The baseline condition was performed at the start of the task in all instances, after completing a 12-throw warm-up set, while the two verbal instruction conditions were counterbalanced across all participants to control for possible order effects (Schorer et al., 2012; Winter & Collins, 2013). Modelled after Wulf et al. (2002) and Gray (2018) to represent the typical step-by-step delivery of real-world instructions (Tse, Fong, et al., 2017), for each condition, participants received a single instruction statement before the initial throw and then for every three throws thereafter (i.e., one rule at a time was provided before trials 1, 4, 7, and 10, following the order listed in Table 1 for each condition), except in the baseline conditions in which participants were only instructed at the start to “throw at the bull’s eye” (Schorer et al., 2012). Participants were asked to listen and repeat the given instruction in each instance to ensure that the information had been heard correctly. Between sets, participants were afforded 2-min breaks (Lohse et al., 2010).

*******Table 1 near here*******

2.4. Statistical analyses and dependent variables

This study employed a 2 (Analogy vs. Explicit) × 4 (Instruction 1 vs. Instruction 2 vs. Instruction 3 vs. Instruction 4) within-subjects design, comprising performance outcome

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(accuracy) and movement (kinematics) measures. The analysis of the four individual instructions within each instruction type prevented the averaging of results across many trials, which could obscure any acute effects of the dependent variables. This analysis also afforded opportunities for intra-instructional comparisons (e.g., analogy instruction one vs. analogy instruction two), which Bobrownicki et al. (2018) argued was a necessary step for analogy and explicit instruction research, as evidence suggests that neither type of instruction may be universally effective (see Poolton, Masters, & Maxwell, 2003). In order to facilitate comparison to the baseline condition, difference scores were calculated for the dependent variables (baseline mean score minus mean score for each instruction) and then employed for the inferential analysis.

Accuracy scores were used as the primary measure of throwing accuracy. To assess joint variability with respect to instructional type, the standard deviation around the mean was calculated for the elbow joint for each throw for all participants and then transformed into coefficients of variation (CV) to eliminate the mean differences between individuals (James, 2004; Lam et al., 2009b). Based on the precedent of Lohse et al. (2010), throw duration (from the dart's first movement away from the dart board, at the start of the throw, through to its release from the hand, at the end of the throw) and angular velocity (from the moment of maximum elbow flexion to the release of the dart) constituted the additional kinematic measures (see Figure 1 for illustration of these measures). Because the throwing movement for one participant deviated from the sagittal plane (i.e., used a "side-arm" throwing style) for four of the six conditions, all her data were excluded from the kinematic analysis (Lohse et al., 2010). Specific trials from five other participants were also excluded for temporarily adopting a side-arm technique, arising from the instruction to "move your arm like a catapult". All effects herein reported as significant at $p < .05$ and any violations of the assumption of sphericity were adjusted using Greenhouse-Geisser procedures.

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*******Figure 1 near here*******

3. Results

3.1. Accuracy scores

A two-way repeated-measures analysis of variance (ANOVA) did not reveal a significant main effect of instruction type on accuracy, $F(1, 19) = .421$, $p = .524$, $\eta^2_p = .02$, although there was a significant effect for instruction number, $F(1.978, 37.582) = 5.579$, $p < .01$, $\eta^2_p = .23$. Post hoc analyses with Bonferroni adjustments indicated that the difference scores for accuracy for the second instruction ($M = -1.82$, $SE = .43$, 95% CI [-2.73, -0.92]) were significantly lower than the first ($M = -0.34$, $SE = .21$, 95% CI [-0.78, 0.10], $p = .005$) and third instructions ($M = -0.76$, $SE = .25$, 95% CI [-1.28, -0.25], $p < .05$) with mean differences, respectively, of -1.48 (95% CI [-2.59, -0.379]) and -1.06 (95% CI [-1.95, -0.17]). Analysis was not suggestive of an interaction between instruction type and instruction number, $F(3, 57) = .873$, $p = .460$, $\eta^2_p = .04$. The difference-scores data are illustrated in Figure 2, while raw data (i.e., prior to difference score calculation) are shown in Table 2.

*******Figure 2 near here*******

*******Table 2 near here*******

3.2. Joint variability

To investigate the effect of instructional type on joint variability, a two-way repeated-measures ANOVA was run on the difference-score CV data. Analysis did not indicate a significant effect for instruction type, $F(1, 14) = .551$, $p = .551$, $\eta^2_p = .04$. There was, however, a statistically significant result for instruction number, $F(3, 42) = 3.899$, $p < .05$, $\eta^2_p = .22$, with pairwise comparisons indicating that variability compared to baseline across both analogy and explicit instructions was significantly higher for the second instruction ($M = 0.05$, $SE = .01$, 95% CI [0.03, 0.08]) than the first ($M = 0.24$, $SE = .01$, 95% CI [0.01, 0.04], $p < .05$). As with accuracy, analysis did not reveal a significant interaction between instruction

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type and instruction number, $F(1.504, 21.062) = 1.659$, $p = .216$, $\eta^2_p = .11$. Figure 2 shows the difference score data, while Table 2 shows the data prior to difference score calculations.

3.3. Angular velocity

Following the trend of the previous dependent variables, ANOVA did not reveal a statistically significant effect for instruction type, $F(1, 14) = .032$, $p = .860$, $\eta^2_p < .01$, but there was a significant effect for instruction number, $F(3, 42) = 4.426$ $p < .01$, $\eta^2_p = .24$. A closer inspection of the data showed that participants demonstrated the slowest angular velocity compared to baseline for instruction two ($M = -79.46$, $SE = 24.81$, 95% CI [-132.67, -26.24]) and the fastest for instruction four ($M = -31.54$, $SE = 14.70$, 95% CI [-63.05, -0.03]). No significant interaction for instruction type and instruction number was detected, $F(1.972, 27.606) = .090$, $p = .912$, $\eta^2_p = .01$. Data for this dependent variable are presented in Figure 2 (difference scores) and Table 2 (data before difference score calculations).

3.4. Throw duration

For throwing time, a two-way repeated-measures ANOVA was run on the difference scores compared to the mean baseline throwing duration. Preliminary examination of the results for this dependent variable indicated that the data for analogy instruction one, explicit instruction two, explicit instruction three, and explicit instruction four deviated from the normal distribution; however, these data were not transformed because recent research suggests that ANOVAs are robust against such non-normality (e.g., Blanca, Alarcón, Arnau, Bono, & Bendayan, 2017; Schmider, Ziegler, Danay, Beyer, & Bühner, 2010) and such transformations render commonly understood units of measurement (e.g., time) difficult to interpret (Myers, Well, & Lorch, 2013). Analysis did not reveal a significant main effect for instruction type, $F(1, 14) = .761$, $p = .398$, $\eta^2_p < .05$, but did show a significant effect for instruction number, $F(1.823, 25.516) = 4.093$, $p < .05$, $\eta^2_p < .23$. Pairwise comparisons indicated that throw duration compared to baseline averages across instruction types was

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significant longer for throw three (M = 0.05, SE = .01, 95% CI [0.02, 0.08]) than for throw one (M = 0.02, SE = .01, 95% CI [-0.01, 0.03], $p < .05$). There was no significant interaction effect found between instruction type and instruction number, $F(1.560, 21.846) = .118$, p = .840, $\eta^2_p = .01$. These data can be found in Figure 2 (difference scores) and Table 2 (raw data prior to difference-score calculations).

3.5. Differences from baseline

To determine if the dependent variables for the instruction types differed significantly from baseline means, one-sample t-tests were employed on the difference score data as a function of instruction. For accuracy, analysis indicated that participants demonstrated significantly less accurate throwing compared to baseline for both analogy, $p = .001$, $d = .84$, and explicit instructions, $p < .001$, $d = .95$. With regard to joint variability, there was also significantly greater variability compared to baseline means for analogy, $p < .005$, $d = .75$, and explicit instructions, $p = .001$, $d = .92$. In terms of angular velocity, a similar trend was detected with significantly less velocity compared to baseline for both analogy, $p < .005$, d = .84, and explicit instructions, $p < .05$, $d = .62$. For the last dependent variable, throw duration, throwing times were significantly longer compared to baseline means for analogy, $p < .005$, d = .77, and explicit, $p = .01$, $d = .66$. Differences compared to baseline means for each instruction within the analogy and explicit instructional sets are indicated in Figure 2.

*******Table 3 near here*******

4. Discussion

Although previous studies have explored and debated the impact of different types of verbal instructions (e.g., internal vs external focus instructions, analogy vs explicit instructions) on motor learning, there has been limited examination of the possible effects of these instructional types on motor control. With this in mind, the primary aim of the present study was to determine the immediate, short-term impact of analogy and explicit instruction

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on movement and performance outcomes. Results indicated that participants not only performed similarly in the analogy and explicit instructions for all dependent variables, but that their performances in these verbal instruction conditions were associated with significantly poorer throwing accuracy scores compared to baseline conditions. These findings correspond to the findings of Shorer et al. (2012) in their investigation of the acute effects for internal and external focus instruction, but contrast with the pattern ordinarily observed in motor learning-focused studies involving analogy and explicit instructions, which have typically featured imbalanced verbal-instruction conditions. It may be that these instructions could eventually benefit the participants with more trials, but it is interesting that the instructions seemed to have detrimentally impacted acute throwing accuracy and even limited a learning effect where it might be expected. The dearth of learning-effect evidence corresponds with similar observations by Schorer et al. (2012) for internally and externally focused instructions.

Along with the accuracy scores, kinematic data further revealed that participants demonstrated significantly more elbow joint variability, significantly slower angular velocity, and significantly longer throwing times in these verbal instruction conditions compared to the baseline conditions. The combination of these results and the accuracy findings correspond with the early stages of cognitive motor learning models and suggest that both the analogy and explicit instructions in motor control contexts may have promoted greater deliberate control of movement compared to baseline and, in turn, disrupted movement in line with Masters' (1992) conscious processing hypothesis. This conclusion is further supported by the limited evidence of any learning effects and the throwing outcome data of Table 3 that show the increase in non-scoring trials and decrease in bull's eye scoring trials compared to baseline for the analogy and explicit conditions.

On the basis of both the present study's results and those of Schorer et al. (2012),

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several types of verbal instructions in motor control contexts (i.e., analogy, external, internal focus, and external focus) have now resulted in less accurate throwing performance than baseline conditions that have only directed participants to “throw at the bull’s eye”. This suggests that the impact of these various verbal instructional types may differ with respect to implementation period (i.e., short-term vs long-term). Given the prevalence of verbal instructions in the field, even amongst elite coaches and competitors (e.g., Porter et al. 2010; Gabbett and Masters 2011), and the positive support for analogy and externally oriented instruction in motor learning contexts, the findings of both this study and Schorer et al. (2012) raise potential questions and concerns regarding the use of verbal instructions in motor control situations specifically. Even if tools such as analogies or externally focused instructions provide long-term learning benefits, it could be unrealistic to expect novices to make immediate use of new verbal information without perturbation to existing movement execution.

Showing correspondence with Bobrownicki et al.’s (2018) predictions concerning potential intra-instructional differences (e.g., analogy instruction one vs. analogy instruction two), there were also significant differences for instruction number with throwing accuracy and kinematics, in particular, impacted for instruction two. One particular issue that could have contributed to these differences—as well as the significant differences in accuracy and elbow joint variability for the verbal instruction conditions compared to baseline performances—was the potential lack of familiarity with—or variable understanding of—the novel verbal instructions, leading to markedly different movement. For example, in this study, the “move your arm like a catapult” analogy instruction generated two distinct movement responses during data collection, with some participants performing the intended, classic catapult movement based on the ancient tension device, while others mimicked the movement of the trebuchet, the counterbalanced mediaeval siege weapon. These differences

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in movement may have had less to do with the *type* of instruction, but more to do with the participants' *interpretations* of those instructions and their familiarity with the concepts therein. Similar issues have been demonstrated previously when the same table tennis analogy (pretend to draw a right-angled triangle with the bat) that was successful for English speakers compared to explicit methods (Liao & Masters, 2001) proved ineffective with Chinese-speaking participants (Poolton et al., 2003).

According to some psychological perspectives, the use and understanding of language varies from person to person (Reed, 1996), so it may be naïve to assume that these difficulties would only apply to analogies and not all forms of verbal instruction. As such, it would seem inadvisable to uncritically apply verbal instructions of *any* kind without first considering the needs, knowledge, and previous experiences of the learner(s), in line with the practices espoused by those such as Abraham and Collins (2011a). If novel verbal instructions are, in fact, creating issues relating to multiple interpretations and, in turn, unwanted movement variability, then consideration in future could be given to eliminating possible ambiguities by incorporating athletes' or participants' own words into the instruction, as suggested by Abraham and Collins (2011a), or by making the instructions as objective as possible, potentially through the use of alternative, more holistic sources of information (SOI; MacPherson, Collins, & Obhi, 2009; Reed, 1996). To date, several case studies have provided tentative evidence supporting alternative SOI, demonstrating the utility of both sonic feedback for optimising speed skating technique (Godbout & Boyd, 2010) and rhythmic SOI for stabilising movement patterns in javelin throwing (MacPherson, Collins, & Morriss, 2008), although the effectiveness and implications of these potential SOI and others (e.g., haptic or visual) for novices still require investigation. It is important to point out, however, that the receipt of novel instructions is not exclusively the domain of novices, so

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issues regarding instructional relevance, familiarity, and understanding should constitute ongoing considerations for expert performers as well.

These considerations notwithstanding, it is important to recognise that there may be some alternative explanations for the observed results. For instance, familiarity with and understanding of the instructions represents one possible reason for some of the differences detected between instruction number. In addition, the second instructions for both analogy and explicit involved more specific information regarding online throwing mechanics than either the first and third instructions, which pertained to dart grip and dart release, respectively. With this in mind, the nature of the movements described by the instructions could account for some of the instruction-number differences. It could also be argued that the lesser variability observed for baseline performances could indicate freezing of degrees of freedom as per Bernstein (1967) in order to simplify control of the human movement system. Given that participants threw more accurately during the baseline condition, however, the results of the study on the whole are more reflective of cognitive models of motor control than the Bernstein-inspired constraints-led or dynamical systems approaches. A third and final alternative explanation could relate to the dart-throwing experience and skill level of the participants, as the verbal instructions could have differentially impacted any participants that were not genuine novices. This study, however, contained inclusion criteria that matched (e.g., could not play more than three times per year; Sherwood et al., 2014) or exceeded (e.g., potential participants that had formal experience in similar throwing or accuracy-based tasks were excluded) common methods for recruiting and categorising novices based on precedent in the literature.

4.1. Future research directions

There are several possibilities for future research that could help to elaborate on or elucidate some of the findings discussed in the present study that would benefit both

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researchers and practitioners alike. For instance, while the methodology of the current study was largely informed by the work of Schorer et al. (2012), which relied on performance outcome and kinematic measures to investigate motor control, future research could look to incorporate electromyography (EMG) or electroencephalography (EEG) measures to gain an even clearer picture of the acute effects of these verbal instruction types. Also, while the present study matched the 50-Hz sampling rate of Schorer et al.'s (2012) dart-throwing study, as well as similar research involving other throwing tasks (e.g., cricket fast bowling; Wormgoor et al., 2010), future studies could aim to draw upon recent technological advances to improve upon these numbers. One further thing that was adopted from Schorer et al. (2012) that could warrant adjustment includes the choice in task. While maintaining the dart-throwing task facilitated comparison across studies and corresponded to similar ballistic tasks previously employed in analogy research (e.g., seated basketball shooting; Lam et al., 2009a, 2009b), it is possible that specific characteristics of the dart-throw movement could have interacted with these verbal instructions, making participants more susceptible to conscious control or explicit monitoring. By extending this line of research to alternative tasks (e.g., gross motor tasks), it could be made clearer whether the observed acute effects of these verbal instruction apply to sport more generally rather than to dart throwing specifically. Arguably, this point of extending the investigation to new tasks could also be extended much more broadly, however, as the literature involving analogy and explicit instruction has focused on a narrow range of tasks over the past 18 years (for list of tasks in analogy and explicit literature, see Bobrownicki et al., 2018).

As the negative effects of instruction in short-term, motor control situations contrast with those in motor learning, another possible avenue for future research could include investigation of the persistence of these acute effects. By increasing the number of trials for each piece of instruction, it may be possible to determine at what point verbal instruction

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begins to benefit performers. While the baseline conditions in this study were always first to ensure that the instructions from the other conditions did not interfere or influence throwing performance, it would also be valuable to know if—and how quickly—performance might return to baseline levels after receiving verbal instruction. With this in mind, a similar study employing a wholly counterbalanced design across all conditions could prove informative for practitioners and researchers alike.

While the step-by-step analogy and verbal instruction used in this study was inspired by real-world practice, provided in accordance with previous methodological precedent (Wulf et al., 2002), and based on both peer-reviewed (Kitsantas & Zimmerman, 2007) and practical coaching resources (Maus, 2000), it is possible that adherence to individual instructions from the analogy and explicit conditions could have differentially impacted accuracy or throwing kinematics. Given the unanticipated advantages for the baseline conditions, future research could look to focus specifically on a single instruction for the analogy and explicit instruction conditions to see whether the pattern of verbal instructions negatively impacting accuracy, as observed in this study and the study of Schorer et al. (2012), continues. Focusing on one single instruction for each instruction condition throughout the study could also address any possible concerns regarding differences in informational volume between the verbal instruction and baseline conditions. While the current study only presented a single instruction at a time to participants in line with conventional coaching practices (Tse, Fong, et al., 2017), taking care to match the overall number of rules of the analogy and explicit instructions, participants will ultimately have received three more instructions in total throughout the delivery of the analogy and explicit conditions relative to the baseline condition. While these differences in instructional volume between verbal instruction conditions and baseline/control conditions have not only been common throughout the existing literature, but also more pronounced because all instructions have typically been

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provided all at once (e.g., Lam et al., 2009b; Liao & Masters, 2001) rather than individually, to better understand the impact of these verbal instructions, more carefully controlling the overall volume of information may constitute a critical consideration for future research involving verbal instruction in motor control contexts specifically. In any such future research, more diverse methods for evaluating the effects of these instructional types, including qualitative interviews, should also warrant careful thought, as the impact of analogy and explicit instruction on other critical aspects of real-world practice, such as motivation, enjoyment, or adherence, for example, has not been explored in the literature to this point. A comparison of imposed analogies (i.e., traditional method) and negotiated analogies (i.e., involving participants in the development of the instruction) might also prove a worthwhile consideration.

4.2. Conclusion

The results of the present study suggest that coaches, physical educators, and sport psychologists should exercise caution when communicating verbal information intended for immediate use in motor control situations, as participants in the analogy and explicit instruction conditions demonstrated reduced accuracy, more deliberate movement, and greater movement variability compared to baseline conditions. This research demonstrates that it may not only be important to consider *how* to instruct movement skills, but also *when* to do so (i.e., motor control versus motor learning situations; cf. Abraham & Collins, 2011b) and *why* (i.e., the purpose). The findings of this study also emphasise the importance of developing and embedding common understanding—first in practice, then in competition—between coaches and athletes with regard to instructions and their intent for movement. In future, given the potential issues pertaining to slower, more deliberate movement and the observed misunderstandings of intent, interested parties may wish to consider exploring alternative SOI, which may offer less ambiguous—and, perhaps, more relevant—information

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sources for learners, such as the use of rhythm proposed by MacPherson et al. (2009). Finally, it is also important to note that the receipt of novel instructions is not exclusively the domain of novices, so issues regarding instructional relevance, familiarity, and understanding should also constitute considerations for expert performers in research and applied practice going forward.

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Figure Captions

Figure 1. Figure depicts the throwing technique and key concepts relevant to the kinematic analyses of the task. Top illustration shows placement of anatomical markers, the start of the kinematic analysis, and the measure of maximum flexion (used for calculation of angular velocity). The bottom illustration explains the measure of angular velocity, elbow flexion at release (used to calculate angular velocity), and the end of the kinematic analysis. Figure inspired by similar model from Lohse et al. (2010).

Figure 2. Mean difference scores compared to baseline means for the four dependent variables as a function of instruction type. Bars denote confidence intervals. * Confidence intervals that do not include zero indicate statistically significant differences from baseline at $p < .05$. (a) accuracy; (b) elbow joint variability; (c) angular velocity; (d) throw duration.

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Table 1. List of instructions for the three instruction types

Instruction type	Instructions
Baseline	Throw at the bull's eye
Analogy	
Instruction 1	Grip the dart as if it were a crisp*
Instruction 2	Move your arm like a catapult to throw the dart
Instruction 3	Follow your hand all the way through the throw like a basketball player finishing his shot
Instruction 4	Imagine that your body has frozen into place and only your throwing arm can move
Explicit	
Instruction 1	Hold the dart with a relaxed, yet firm grip
Instruction 2	Leading with your elbow to start, move your hand back with the dart, and, in one motion, throw the dart toward the board
Instruction 3	As you complete your throw, extend and point your fingers toward the target
Instruction 4	Keep your body, legs, and left arm stationary throughout the throw and let your right arm do all the moving

*Potato chip in American English

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Table 2. Descriptive statistics for the dependent variables for each instruction prior to difference score calculation.

	Baseline	Analogy				Explicit			
		Instruction 1	Instruction 2	Instruction 3	Instruction 4	Instruction 1	Instruction 2	Instruction 3	Instruction 4
	M (SE)	*M (SE)*	*M (SE)*	*M (SE)*	*M (SE)*	*M (SE)*	*M (SE)*	*M (SE)*	*M (SE)*
Accuracy (score)	7.02 (.19)	6.72 (0.29)	5.03 (0.53)	6.35 (0.39)	6.42 (0.27)	6.97 (0.34)	5.68 (0.46)	6.48 (0.27)	6.08 (0.53)
Joint variability (CV)	0.38 (0.02)	0.40 (0.19)	0.42 (0.02)	0.43 (0.03)	0.42 (0.02)	0.41 (0.02)	0.45 (0.03)	0.42 (0.02)	0.41 (0.02)
Angular velocity (deg/s)	375.91 (34.23)	336.78 (30.00)	302.35 (31.19)	322.68 (29.31)	342.34 (30.43)	338.43 (31.63)	300.50 (29.91)	318.22 (32.46)	350.34 (33.74)
Throw duration (s)	0.15 (0.01)	0.16 (0.01)	0.20 (0.02)	0.21 (0.02)	0.17 (0.01)	0.17 (0.01)	0.20 (0.02)	0.21 (0.02)	0.17 (0.01)

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Table 3. Throwing outcomes as a function of instruction type

	Baseline			Analogy			Explicit		
	Total	*M*	*SE*	*Total*	*M*	*SE*	*Total*	*M*	*SE*
Bull's eye scoring trials	4	0.20	0.04	2	0.10	0.02	3	0.15	0.03
Non-scoring trials	1	0.05	0.01	13	0.65	0.14	16	0.80	0.18
Accuracy score	1723	86.15	19.26	1471	73.55	16.45	1513	75.65	16.92

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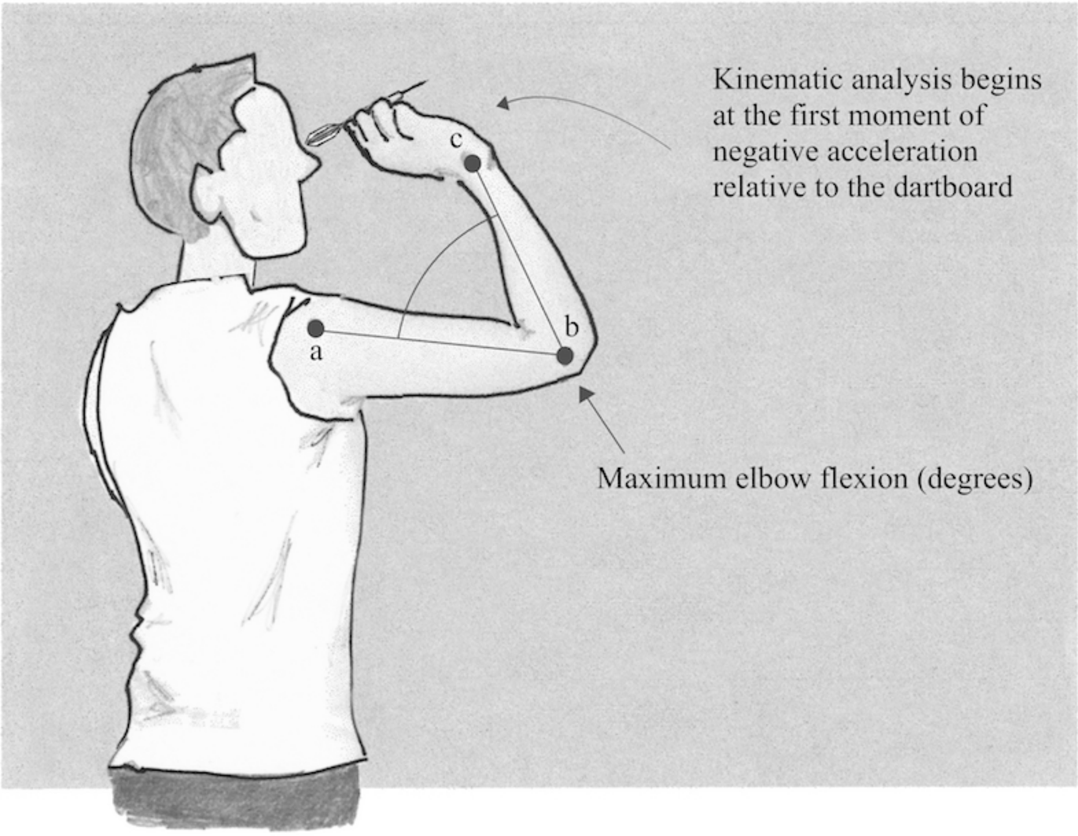
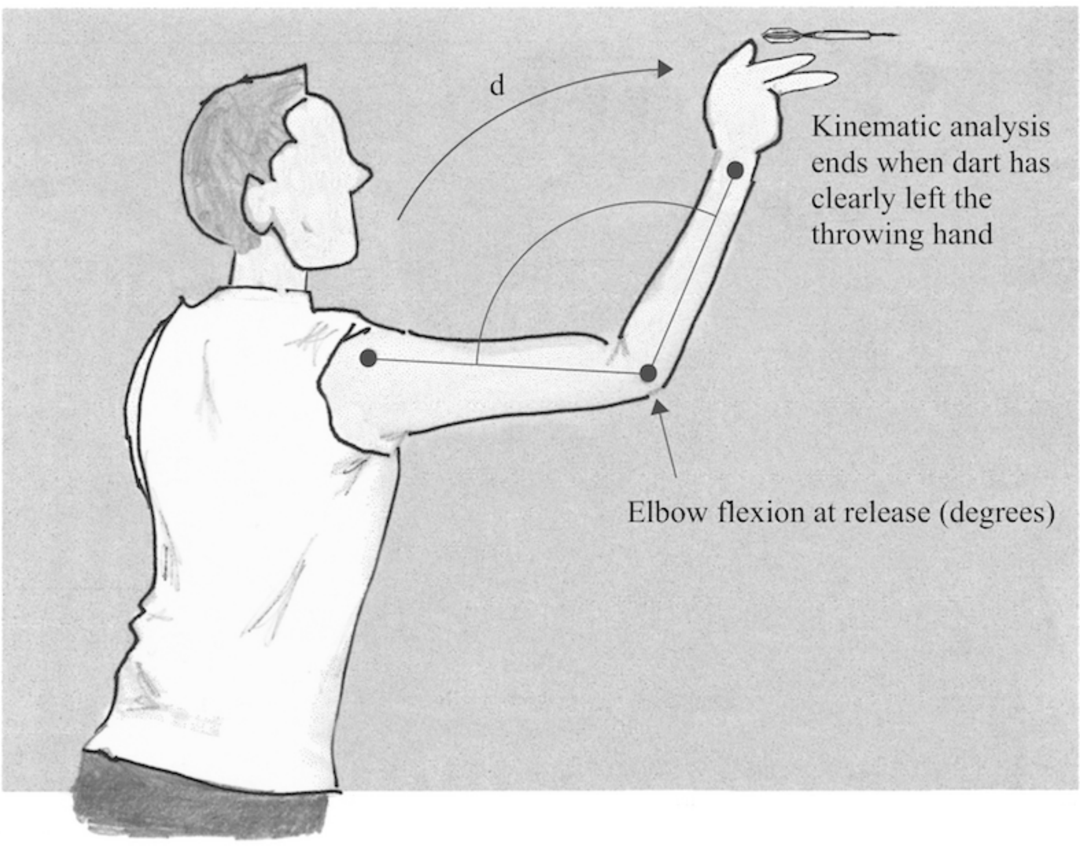


Contrasting anatomical markers for the kinematic analyses were placed on the:
a) Acromion process
b) Lateral epicondyle
c) Styloid process



d) Angular velocity calculated by dividing the difference between elbow angle at extension (release) and at maximum flexion by the time.

Figure 1. Figure depicts the throwing technique and key concepts relevant to the kinematic analyses of the task. Top illustration shows placement of anatomical markers, the start of the kinematic analysis, and the measure of maximum flexion (used for calculation of angular velocity). The bottom illustration explains the measure of angular velocity, elbow flexion at release (used to calculate angular velocity), and the end of the kinematic analysis. Figure inspired by similar model from Lohse et al. (2010).

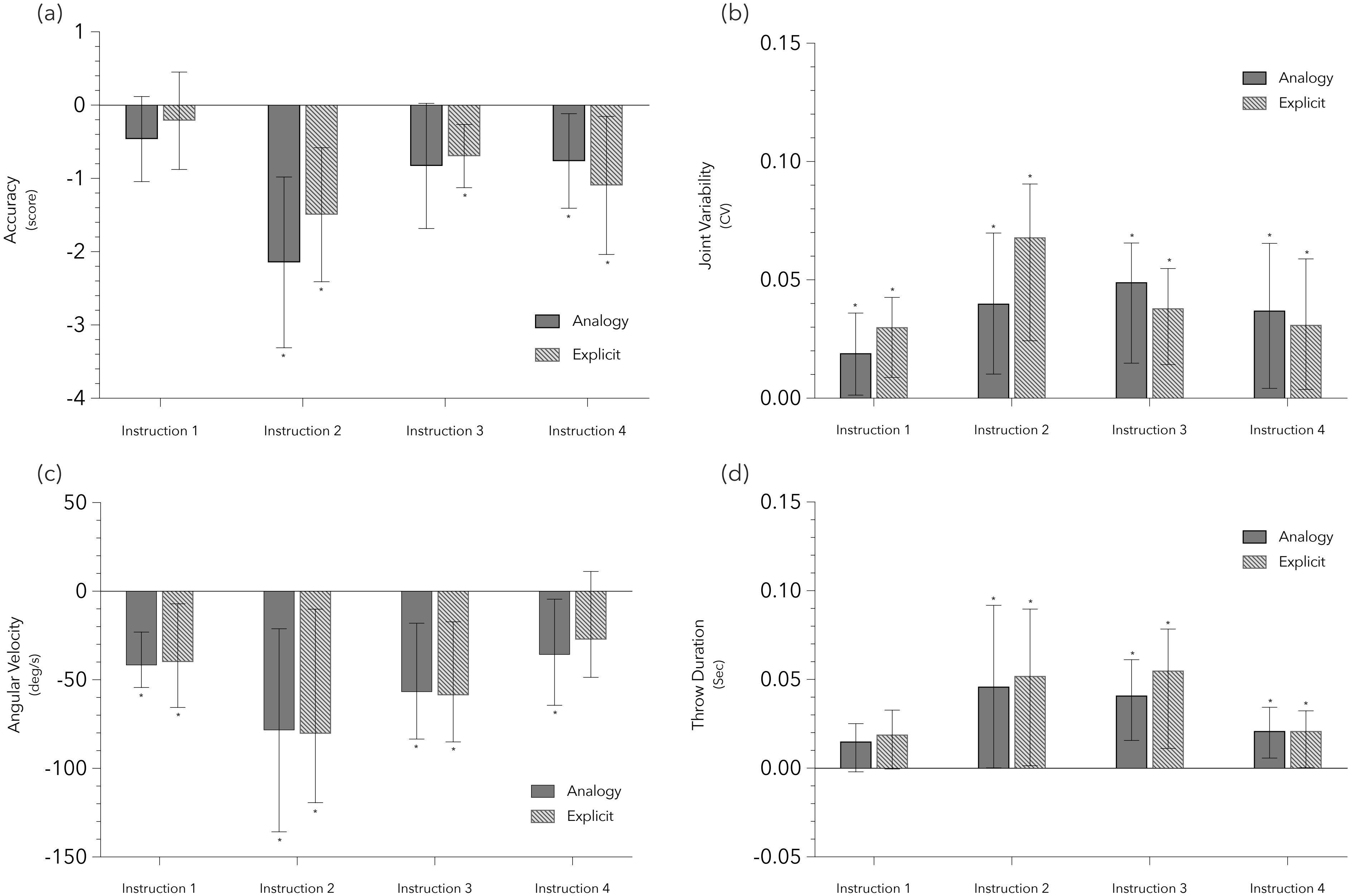


Fig. 2. Mean difference scores compared to baseline means for the four dependent variables as a function of instruction type. Bars denote confidence intervals. * Confidence intervals that do not include zero indicate statistically significant differences from baseline at $p < .05$. (a) accuracy; (b) elbow joint variability; (c) angular velocity; (d) throw duration

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Highlights

- When using analogy or explicit instructions in motor control contexts, participants did not exhibit any statistically significant differences.
- Compared to baseline means, participants during the analogy and explicit instruction conditions demonstrated significantly less accuracy, significantly greater elbow joint variability, significantly slower angular velocity, and significantly longer throwing times, suggesting that these two instruction types may have engendered similar levels of conscious movement control.
- Findings suggest that verbal instruction may differentially affect performance in motor control situations, compared to motor learning, indicating that sport psychologists, coaches, and other applied practitioners should carefully consider the purpose and timing of instructions in acute performance contexts.

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AUTHOR DECLARATION

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

We further confirm that any aspect of the work covered in this manuscript that has involved either experimental animals or human patients has been conducted with the ethical approval of all relevant bodies and that such approvals are acknowledged within the manuscript.

We understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office). He is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. We confirm that we have provided a current, correct email address which is accessible by the Corresponding Author and which has been configured to accept email from ray.bobrownicki@uws.ac.uk.

Signed by all authors as follows:

Ray Bobrownicki	10 April 2019
Alan MacPherson	10 April 2019
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John Sproule	10 April 2019

(Updated for April resubmission)

ACCEPTED MANUSCRIPT